

# The Digital Optical Module System for IceCube

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IceCube is a proposed neutrino detector to be located at the South Pole. It will consist of 80 strings, each string having 60 optical modules located at depths from 1400 m to 2300 m. With a horizontal spacing between strings of 125 m, the enclosed volume will be approximately one cubic kilometer. The cables connecting the optical modules to the surface will be of the order of 2.5 km long. Given this long length and the finality of modules frozen in the ice, the choice of technology for bringing the information from optical module to surface becomes paramount.

LBNL has proposed a fully digital technology in which the signal from the photomultiplier tube is digitized in the optical module (the Digital Optical Module, or DOM), and all information is sent to surface in digital form. This makes it possible to preserve the fast timing information of the PMT anode signal and, at the same time, use rugged copper connectors and cables to join the surface electronics to the modules at depth. Additional features include waveform digitization at speeds of 500MHz, a local coincidence timing requirement among adjacent modules, automatic time synchronization and calibration, multiplexing of several modules on a single twisted copper pair, and remote control of the system.

Forty-one DOMs were deployed at the South Pole in January, 2000 as a part of the AMANDA II array. They all worked at the time of deployment and all but three continue to function one year later. The three failures, as far as we can tell, originate with the PMT base, and not with the electronic components designed and built at LBNL.

The system can be operated remotely via the Internet. Indeed, from a desktop computer at LBNL it is possible to "talk" to an individual optical module 8000 miles away and 2 km deep in the ice. We can test out new firmware and

software in the lab, and then download it to a DOM and demonstrate it in the field. This capability - remote operation without requiring human intervention at Pole - will also be incorporated in IceCube.

Monitoring of the performance of the DOM system and the gathering of limited data proceeded practically automatically over the year since deployment. Intervention was required occasionally for unscheduled power interruptions. The operating parameters of the DOMs (voltages, currents, etc.) were logged. More interesting quantities such as PMT wave forms (recorded with a custom low-power chip, the Analog Transient Waveform Digitizer) were also sent back daily via satellite. A particular example of the capability of digital technology was the measurement of temperature in the DOM. Weeks after the initial freeze-in of the hole, the sensors in each DOM were still recording small changes in temperature as heat flowed in the surrounding ice. Since there were 41 DOMs spaced 12 meters apart, the variation of temperature with depth was also evident.

During the year since deployment, the results obtainable have been limited by the surface DAQ. A partial remedy for this was the construction of four individual, mini-DAQ boards, each of which could communicate with one DOM. These were brought to the Pole in the 2000-2001 season and, using them, it was possible to demonstrate one of the key features of the digital system - the calibration of the local oscillator in the DOM. A timing resolution of 5 nanoseconds was obtained, which meets the requirements for IceCube.

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